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ARRAY OF METALLIC SINGULARITIES FOR THE HIGH DENSITY CELL PLACEMENT ON A MICROFLUIDIC CHIP

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ABSTRACT

Dielectrophoresis is an efficient technique often used to handle or trap micro-/nano-particles within microfluidic devices. For that purpose, arrays of insulating materials disposed between polarization electrodes are classically used to generate the necessary dielectrophoresis forces. In this paper, a novel method is proposed where metallic micro dots are arrayed to generate strong field inhomogeneities, that permit the efficient cell placement as an array. As these micro dots are not connected (electrodes with floating potential), high density of dielectrophoretic traps can be achieved.

We demonstrate in this paper the capability to trap particles using such metallic micro dots array with high density.

KEY WORDS: Dielectrophoresis, microarray, microfluidics, cell handling

INTRODUCTION

Over the past 10 years, dielectrophoresis (DEP) has known an increasing interest in a large amount of domains: biosensors, cell therapies, drug discovery, medical diagnostics, microfluidics, nanoassembly and particle filtration [1]. DEP induces the motion of a particle because of its polarization in a non uniform electric field [2]. Different kinds of dielectrophoretic patterns have been investigated for cell handling and sorting [3,4,5]. Among the developed configurations, the idea to create dielectrophoretic forces thanks to the introduction of micro patterns between the polarization electrodes is fully implementable in microfluidic biochips and well suitable for single cell trapping or the trapping of cells as a high density array. Most often these micro patterns are made out of insulating materials, patterned within the fluidic structures [6]. Here we propose an alternative method based on the use of conductive dots arrayed within a microfluidic channel. This allows enhancing drastically the electrical field inhomogeneities, and therefore produces strong DEP forces allowing the efficient arraying of particles. Moreover the proposed method might permit to create high aspect ratio tips capable to strongly enhance the DEP effect. We describe in the next section the design and fabrication of the proposed microfluidic chip. Experimental results are then presented.

DESIGN AND FABRICATION

Figure 1 shows the structure of the biochip we developed. Polarization electrodes (made of gold, thickness = 4µm) are distant from 200 µm. The microchannel is defined by theses thick gold electrodes, to which is superposed a patterned SU8 layer (photosensitive resist from MicroChem) in order to obtain the desired channel height set to 25 µm. In the microfluidic channel, between the polarization electrodes, an array of dots which diameter is 20 µm is patterned.

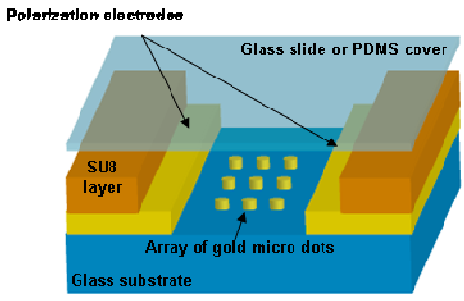

Figure 1: Structure of the microfluidic biochip (arbitrary scale).

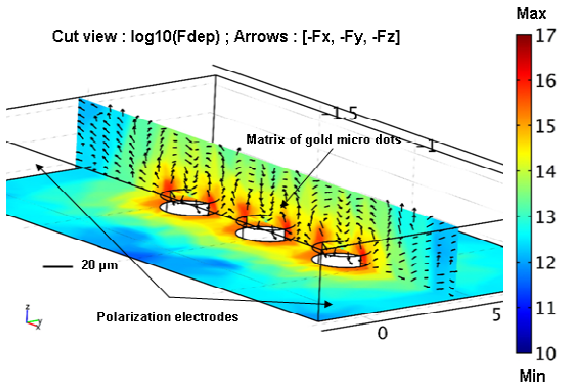

Figure 2: Finite element analysis of the DEP force (F_{DEP}) in the microfluidic channel.

A finite element analysis (COMSOL Multiphysics ©) shows the DEP force inside the microfluidic channel. Figure 2 shows the DEP force topology (case of negative DEP), that traps the particles to the top of the metallic dots.

The microfluidic chip was fabricated as follows: a glass wafer was used as substrate for its transparency and dielectric properties. A Cr/Au (50 Å /150Å) layer was evaporated on its surface. The gold layer thickness was then increased up to 4 µm by electroplating. Photolithography was used to pattern the gold electrodes (Figure 3), and the SU8 microfluidic channels.

The biochip was finally packaged using two different ways i) a microscope glass slide (t=170 µm), simply covering the chip ii) a PDMS layer bonded to the chip after silanization. Fluidic inlets and outlets were created by drilling in the glass slide or punching the PDMS cover (Figure 4).

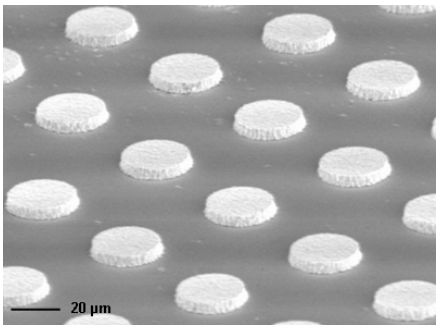

Figure 3: SEM view of the electroplated gold dots.

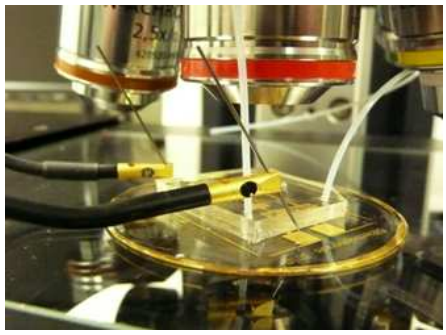

Figure 4: View the microfluidic chip under the microscope.

EXPERIMENTAL RESULTS

First experiments were lead in static conditions with polystyrene beads (typical diameter of 10 µm comparable to a biological cell diameter). These particles were suspended in ultra pure water with a concentration of 10^6 particles/mL. A 10 V sinusoidal voltage was applied between the polarization electrodes with a frequency of 100 kHz.

As shown on Figure 5, in these conditions, the particles exhibited a negative DEP behavior. Without any voltage, the particles were randomly positioned and, as expected, when the voltage was applied, the particles were attracted on the gold dots. These first results demonstrated the efficiency of the proposed DEP micro patterns.

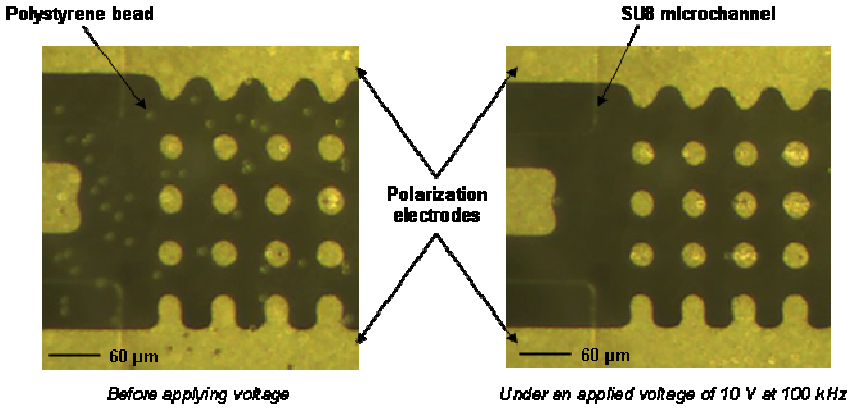

Figure 5: Gold dots and particles within the fluidic chip: particles are arrayed under an applied voltage of 10 V at 100 kHz.

We demonstrated here the feasibility of using metallic dots microarray as powerfull mean to array particles within a microfluidic structure. Indeed experimental validations prove that the proposed gold micro dots are well suitable for cell trapping, as they provide strong DEP forces. We are now improving the geometry of the proposed micro dots, including tip effects as a very promising tool for single cell trapping and positioning.

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